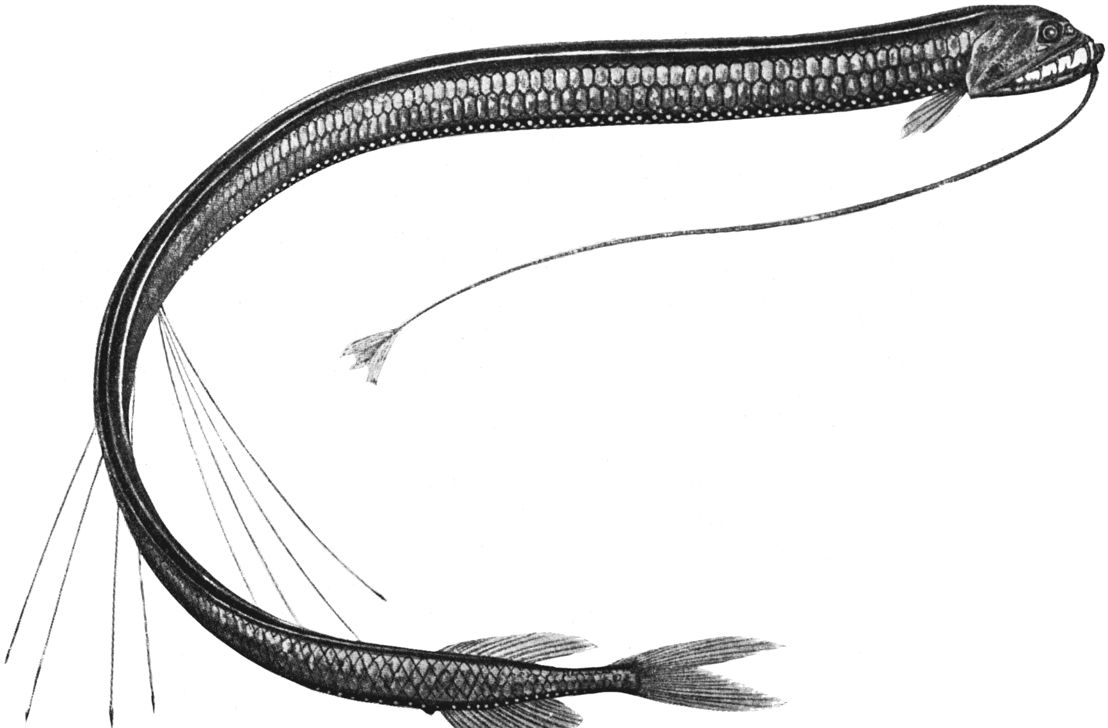
IV

THE DEPTHS OF THE SEA

ALL who have taken any interest in the investigation of the sea during the last years will know the *Michael Sars,* and the work done by her scientific staff in the North Sea. Later she investigated the Atlantic and starting from Norway, she made for the Canaries, from the Canaries to the Azores and thence through the Sargasso Sea to St. John's, Newfoundland, and so back to Glasgow. The ship was built by the Norwegian Government in 1900 to undertake researches into the Norwegian fisheries in connexion with the international scheme of North Sea investigation and to study the conditions under which these fisheries exist. She is essentially a first-class fishing trawler, specially fitted for scientific work. Her length is about 120 feet and her gross tonnage 226. Her engines are 300 horse-power and can keep up a uniform rate of ten knots; but her coal storage is small, a serious consideration when the Atlantic is to be crossed.

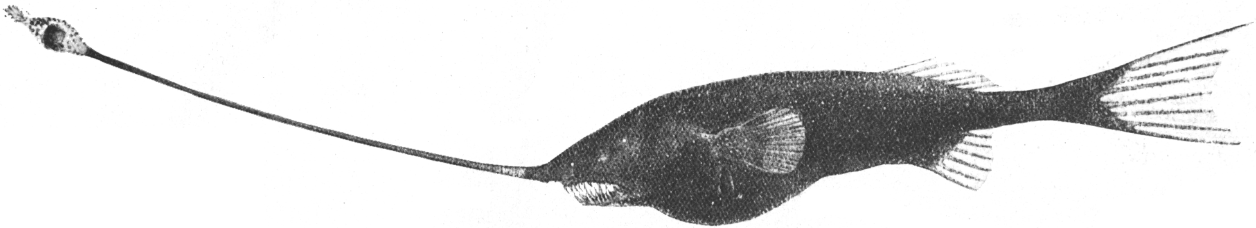
There are many reasons for keeping a research ship of this kind small, not the least being the cost of up-keep, but it was somewhat of an experiment to take so small a vessel for a prolonged ocean trip; yet no one who reads the account of the voyage[1] can fail to perceive that the experiment has

[1] "The Depths of the Ocean," a general account of the modern science of Oceanography based largely on the scientific researches of the Norwegian steamer *Michael Sars* in the North Atlantic. By Sir John Murray, K.C.B., F.R.S., etc., of the *Challenger* Expedition, and Dr. Johan Hjort, Director of Norwegian Fisheries. With contributions from Professor A. Appellöf, Professor H. H. Gran, and Dr. B. Helland-Hansen. Macmillan, 1912.



Macrostomias longibarbatus (*Stomiatidæ*)

Gulf of Guinea. 1880 m. Natural size. Having a light-organ under the eye, 18 between the gill-slits, and on each side 146 in the lateral line and 179 in the ventral line.



Gigantactis Vanhoeffeni

Western part of Indian Ocean. At depth of 1500 m. × 2.

proved eminently successful. This is, in our opinion, largely due to the fact that the men of science on board, as well as the crew, were not only exceptionally able men, but were men who thoroughly knew their boat and its capabilities. The list of the scientific staff contains some of the best known names in oceanographic research. Each of them is a master in his own subject, and each is a bold experimenter, and through them new methods and new machinery which were successfully employed on this Atlantic cruise, have been given to the world.

The greater part of the record of the voyage is written by Dr. Johan Hjort; but there are contributions by Sir John Murray, Professor Appellöf, Professor Gran, and Dr. Helland-Hansen. The first chapter is largely an abstract of Sir John Murray's able history of oceanographic research that precedes the summary volumes of the *Challenger* Expedition. The abstraction, indeed, is so complete that little more than a string of names and figures is left, though to some extent the material is brought up to date by the mention of the numerous expeditions which have taken place in the last thirty or forty years. The meagreness of the references to the work done by the steamers belonging to Zoölogical Stations, such as the *Huxley,* by the Fishery Board of Scotland with its steamer the *Gold-seeker,* and by the Irish Fishery Board, is perhaps made good by the recent publication of "The Biological Stations of Europe," by Professor Kofoid, under the auspices of the United States Bureau of Education. Sir John Murray's real contribution to the book is an invaluable chapter of some eighty pages, on "The Depths and Deposits of the Ocean," illustrated by three beautiful plans. This is an authoritative and adequate presentment of a subject which he has made his own.

The passengers and the crew of a liner racing over the surface of the Atlantic are apt to imagine that under them is a vast layer of water of varying depth sparsely inhabited by a few fish. As a matter of fact, the whole of this great ocean is teeming with life. If, instead of taking ship, we could take to the water and walk across the bed of the Atlantic to America, starting from the shores of Western Europe, we should in effect be travelling through a succession of new countries. Not only would the surrounding physical conditions vary as we advanced, but the animal and plant life would vary in correlation with the altering physical conditions. We should soon leave behind us the larger seaweeds of our childhood, such as the bladderwrack, and the belt of mussels, barnacles, limpets, periwinkles, dog-whelks and small crustacea, sea-anemones and worms, which for the most part inhabit the sea-beach between the upper and the lower level of the tide. Just about the limit of low water of high spring tides we should encounter a somewhat richer fauna and flora. In place of the bladderwrack we should find *Laminaria;* also blennies, gobies, and other small fish, together with the larger crustacea such as crabs and lobsters, hermit-crabs and prawns. Clams and scallops would also be seen; while the molluscan whelks and horse-mussels would still occur. Worms we should find crawling in and out of crevices and tubes in the sand, sea-urchins resting on the bottom; or,

"lilting where the laver lingers,
The starfish trips on all her fingers."

Encrusting organisms, such as hydrozoa and polyzoa, are here at work clothing rocks and stones, and shells of other animals. Here, too, will be found an abundance of brightly coloured sponges, while sea-anemones—"those flowering stomachs," as George Meredith calls them—will be still as plentiful as in the rock-pools left behind.

The nature of this tract would of course vary with the bottom deposit. The fauna we have described in the main belong to a gravel and stone strewn floor. But much the same progressive change in the animal life would be found if we set out on our journey along a rocky outspur running into the sea, with this difference: that limpets would be clinging and barnacles anchored to the rocks. Should we start, however, from a flat and sandy shore, we should miss the large, sessile seaweeds and find instead numerous lugworms and many of the small crustacea such as the copepods. On the whole, the sand supports a poorer fauna, though on the sand the *Zostera,* a vivid green ribbon-like flowering plant, gives its name to the next zone we traverse.

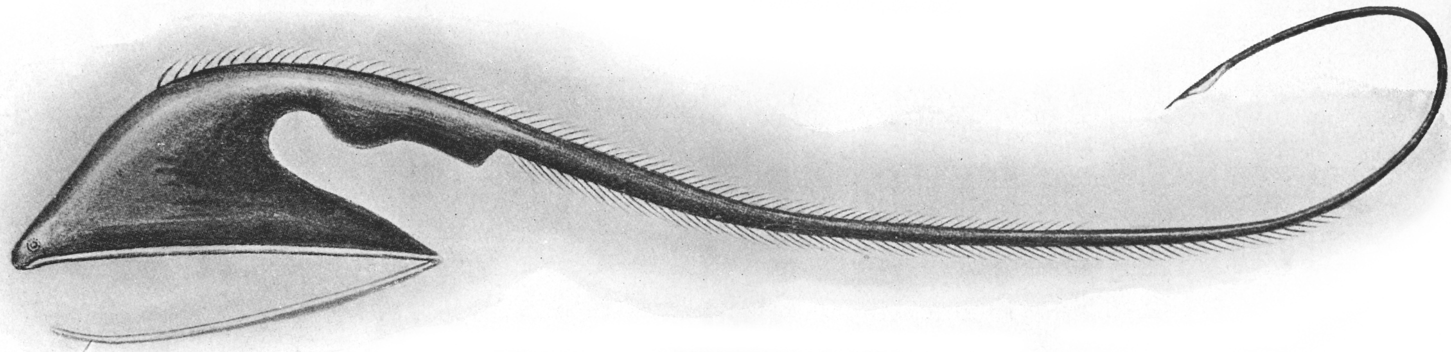
Walking further and further towards the depths of the Atlantic, we should soon lose all sight of the algæ; and the shallow-water fish, the plaice and sole, whiting, skates, dogfish and others, and cod, would give way to the megrim and the hake. The sea-floor would gradually change from rock or gravel or stones to sands, and ultimately to mud or oozes of various tints, their original colours often modified by the action of the decomposition of organic particles in them and on them. All these deposits are derived from the neighbouring land and are blown seaward by off-shore winds or washed down by rains and streams and carried out to the sea by rivers.

The distance to which fine matter in suspension may be carried is very great. The Congo is said to carry its characteristic mud as far out to sea as 600 miles, and the Ganges and the Indus as far as 1000 miles. Except in the neighbourhood of such great rivers, a subaqueous traveller would soon pass beyond what Sir John Murray has called the "mud-line," a line that limits the terrigenous deposits everywhere surrounding dry land. Having reached this limit we must proceed warily, for at the mud-line, at an average depth of 100 fathoms, we shall find ourselves at the edge of the *continental shelf,* that rim which extends seaward to a varying distance from all land areas, the rim on which Great Britain rests. Beyond lies the *continental slope,* a precipice more or less abrupt and more or less high, descending by steep declines or terraced cliffs until depths of 2000 fathoms are reached.

The deepest ocean-pit as yet sounded lies in the Pacific. It is 31,614 feet deep, thus surpassing by 2612 feet the height to which Mount Everest rises above the mean ocean-level. Roughly speaking, the heights to which the higher mountains rise above sea-level is paralleled by the depths to which the deepest "deeps" sink below that level. Yet, as has often been pointed out, these inequalities are negligible as compared with the diameter of the earth, and could we shrivel up our globe to the size of an orange, mountain ranges and abysmal depths would be no more prominent than the rugosities of the orange skin. It may be added that if all the elevations on the earth were removed and filled into all the hollows, we should have a world smooth as a billiard-ball and completely surrounded by an ocean 1450 fathoms deep. This is called the "mean sphere level."

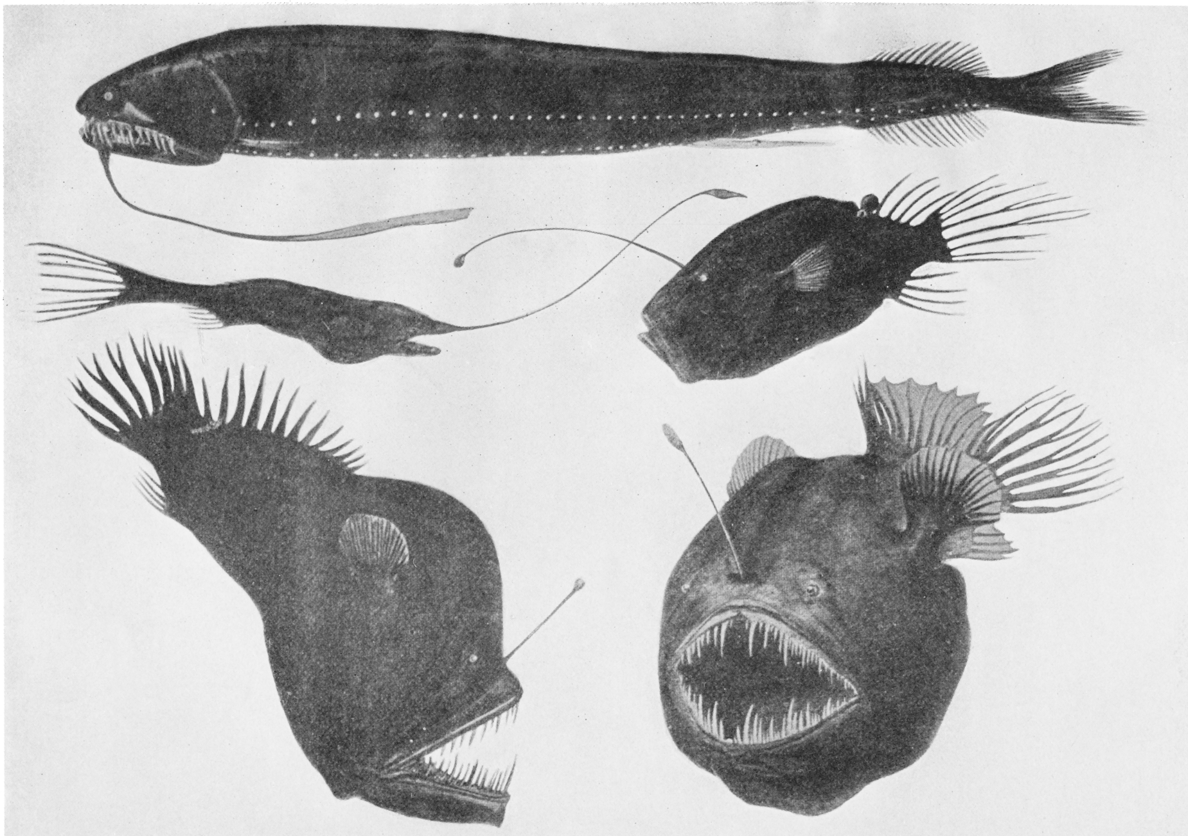
The Atlantic has an average depth differing but little from the "mean sphere level." Compared with the other great oceans, it has an unusually large area of comparatively shallow water. Of its total area 27.5 per cent. is covered by water less than 1000 fathoms deep; 18 per cent. lies between 1000 and 2000 fathoms; and 47 per cent. between 2000 and 3000 fathoms; the remaining 7.5 per cent. is still deeper.

At the foot of the continental slope lies an illimitable



Megalopharynx longicaudatus (*Eurypharyngidæ*)

Gulf of Guinea. At depth of 3500 m. × 1.5.



Pelagic Deep-sea Fish

a. *Melanostomias melanops* (*Stomiatidæ*). Indian Ocean (near Achin). Trawl to depth of 1024 m. Slightly reduced.
b. *Gigantactis Vanhoeffeni* (*Ceratiidæ*). Indian Ocean (east of Zanzibar). Within depth of 2500 m. Natural size.

plain, of a uniform dull, greyish-buff colour, flat and featureless as the desert, and only diversified by an occasional as yet uncovered rock or wreck or the straight line of a recently laid cable. This plain continues with hardly a change in scenery or in level until we approach the great mid-Atlantic ridge. As Bruce has shown, this ridge, which roughly bisects the Atlantic, extends from Iceland as far south as 53° of south latitude, with a slight and quite inexplicable break just under the equator. The ridge runs almost parallel with the eastern contour of North and South America, which in turn, as the ordinary map will show, roughly corresponds with the western contour of Europe and Africa. From time to time the ridge rises above the surface of the water, as in the Azores group, St. Paul's Rocks, Ascension, Tristan da Cunha, and Gough Island.

Having ascended the eastern and descended the western slope of this mid-Atlantic ridge, we should again traverse plains of greyish ooze far more extensive than any level land tract known to geographers, and as we approached the American coast we should gradually pass through, in reverse order, the zones of life traversed when leaving Europe. On the eastern coast of America the slope is much more gradual than on the western coast of southern Europe and Africa. Moreover, the terrigenous deposits of North America extend further to sea. This is mainly due to the fact that the winds of the North American coast are, as a rule, off-shore, whereas those of the Old World are mostly on-shore. It is common knowledge that our "weather" comes from the west. Here and there on the wearisome, monotonous scene we have mentally traversed would be seen, half immersed in the ooze, some yet uncovered rock or stone dropped by a passing iceberg, or a piece of pumice thrown out by some volcano, which, after floating about on the surface for a time, has become water-logged and dropped to the bottom; or, again, the wreckage of men's ships,—

"The wrecks dissolve above us: their dust drops down from
afar—
Down to the dark, to the utter dark, where the blind white
sea-snakes are,"—

or the bones and skeletons of whales and fishes and sea-birds lie awaiting burial by the ceaselessly falling *Foraminifera*.

If we examine a specimen of the ooze just described we shall find it consists of countless millions of small, microscopic, chalky shells, the innumerable homes of unnumbered unicellular animals, which, when alive, floated on the surface of the ocean. The great mass of these belong to the group of *Foraminifera,* microscopic animals which have the power of secreting calcium carbonate from the sea-water and building it up into shells of many chambers. These shells, compacted together, form the white cliffs of our coasts and the chalk downs of our southern coasts. *Foraminifera* are capable of extraordinarily rapid reproduction, and at times the surface of the sea is almost packed with them. No less than 22,500,000 square miles of the Atlantic bed is covered with the shells of these organisms. Some twenty kinds have been classified. The commonest genus amongst them is the *Globigerina,* and hence the deposit itself is known as *Globigerina* ooze. At what rate the deposits thicken we do not know, but those whose business it is to lay marine cables have evidence that in some places about one inch is deposited in ten years. Like other unicellular, floating organisms, *Foraminifera* are kept floating whilst alive by the secretion of either air bubbles or oil globules lighter than water. When the animals die the floats cease to act and their bodies sink slowly down in a never-ceasing rain of marine dust, covering and obliterating inequalities on the ocean floor, and clothing the sea-bottom with a mantle of monotony.

These monotonous plains, which Kipling has called

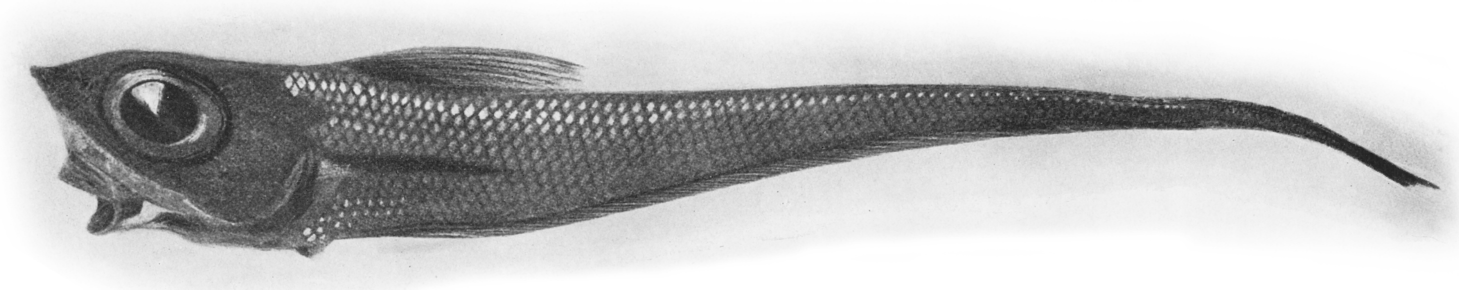
"The great grey level plains of ooze,"

are, as a rule, at a depth of about 2000 fathoms: only in a few places does the Atlantic bottom sink over 3000 fathoms below the level of the ocean surface.

While the main area of the Atlantic is covered by the *Globigerina* ooze, there are a few small tracts off the western coast of northern Africa and around the Azores where this deposit is replaced by the shells of certain floating or pelagic molluscs known as pteropods. Again, there are comparatively large tracts, one forming a wide and irregular ring round the Bermudas, another an irregular patch to the west of the Canaries, in which red clay takes the place of *Globigerina* ooze. Red clay is much more abundant in the Pacific Ocean, and is probably the most widely distributed of all deep-sea deposits. Usually of a reddish colour, at times it passes into a dark chocolate hue due to the presence of a number of small grains of pyroxide of manganese. As a rule, red clay contains little or no calcareous shell matter, but flinty or siliceous organisms, sponge-spicules or the skeletons of *Radiolaria* or of diatomes are often to be found in it. The most constant of its inorganic elements is pumice in all stages of disintegration. Oxides of iron and manganese nodules, either as minute granules or as secretions round other remains, not infrequently attain the size of marbles.

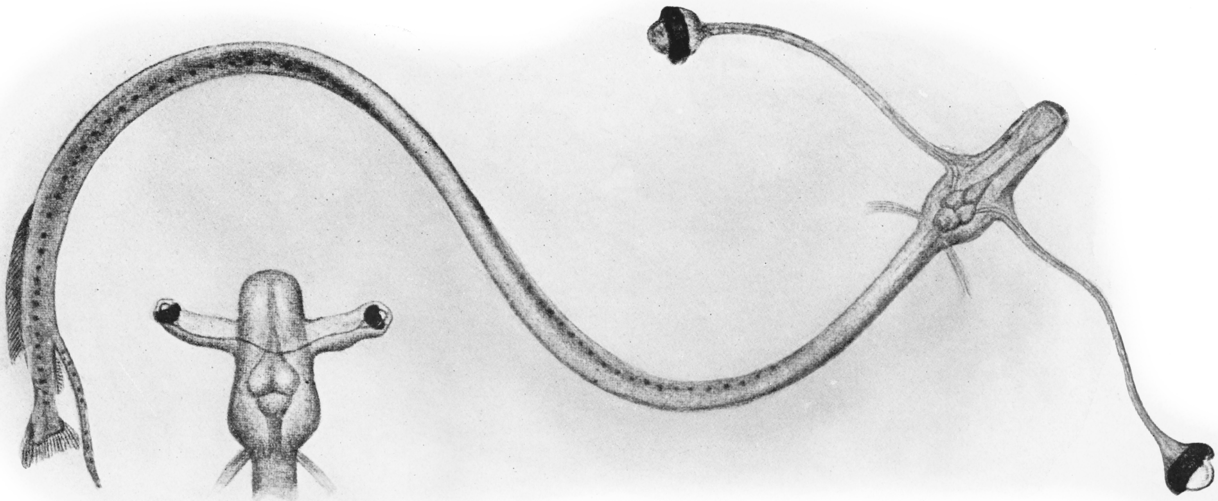
Under certain circumstances, and if exposed for long periods of time, the thin calcareous shells of the *Foraminifera* are soluble in sea-water, and thus it comes about that at a depth of some 2500 fathoms the *Globigerina* shells are dissolved and so never reach the bottom. In their place we find at depths, say below 3000 fathoms, the bed of the sea covered either with volcanic material or with flinty *Radiolaria* skeletons, or, still more rarely, with a diatome ooze, also siliceous. Like the *Foraminifera,* the *Radiolaria* are unicellular organisms buoyed up by floats of various kinds on the surface of the sea. But instead of secreting a skeleton of carbonate of lime, their skeleton is composed, like that of many sponges, of spicules of flint or silica. This substance is much less soluble in water than chalk, and consequently radiolarian ooze covers a considerable area of the sea bottom in the very deep waters of both the Pacific and Indian Oceans. The second siliceous deposit is distinguished by the predominance of the skeletons of the lowly forms of plant life, the diatomes. This deposit is particularly associated with a band across the north of the Pacific and a great girdle round the Antarctic land.

In describing this imaginary journey across the ocean bed we have spoken of the things we should "see"; but in reality we should see nothing at all unless we were gifted with the power of seeing in the uttermost darkness. At the bottom of the Atlantic a darkness prevails with which the blackest night on land would seem comparatively twilight. No ray of sun or moon can pierce through anything like 2000 fathoms of water, and the only light ever seen at these great depths is due to the phosphorescence of certain of the deep-sea organisms. How far this phosphorescence is visible is still a matter about which we want more knowledge. We know that these luminiferous organs vary immensely in complexity and in power. Many of the lower light-givers (invertebrates) secrete a luminous mucus or slime, but others, especially the fish, have very highly organised luminiferous organs as complex as eyes, and these are segmentally situate, so that in walking across the ocean bed we should



Cælorhynchus fasciatus Günther (*Macruridæ*)

Agulhas Cape. 500 m. Somewhat reduced.



Young Stage of Fish from the Equatorial Indian Ocean with Stalked Eyes

Within depth of 2000 m. ×9. All specimens have a long appendage in front of the hind fin. On the left is shown the head of a young specimen with shorter and broader eye-stalks—a type which was caught repeatedly in the depths of the Antarctic Ocean.

from time to time see a blurred glare at our feet, like an ineffective lamp in a London fog, and from time to time a fish would pass gleaming from prow to stern with rows of lights, like a miniature liner with her port-holes all aglow.

The poet has told us that:

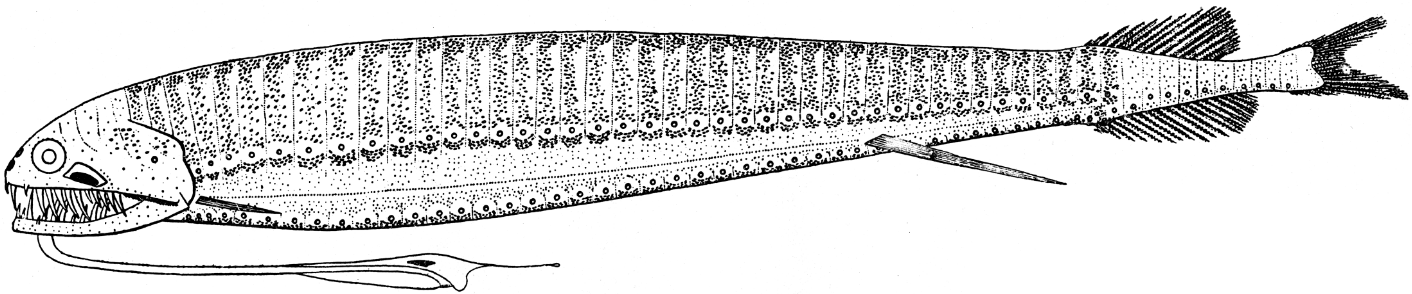
> "The sun's perpendicular rays
> Illumine the depths of the sea."

But the poet is only partially right; the sun's rays do not really reach the depths. Till the transatlantic voyage of the *Michael Sars,* the limit to which light penetrated the ocean water was generally thought to be at about 300 fathoms. But Dr. Helland-Hansen, the author of the illuminative chapter on "Physical Oceanography," has devised a new and more perfect photometer than any that has hitherto been used at great depths. At its very first trial, near the Sargasso Sea, the apparatus acted perfectly. As far down as 500 fathoms the photometer registered light, and in considerable quantities; but at a depth of roughly 850 fathoms the most highly sensitive photographic plates were unaffected even after an exposure of two hours. This apparatus is figured on page 249 of the volume, and is obviously a great advance upon anything that has hitherto been used. Very sensitive pan-chromatic plates were used, and the result of the experiments made at noon on the 6th of January, 1910, with a clear sky, "show that a good deal of light penetrates to a depth of 1000 metres—considerably deeper than was previously supposed." At 50 fathoms the rays were of all colours, though red rays were beginning to fade out; at this depth the red rays were, in fact, fewer in number than the green; blue and ultra-violet rays already predominated. At 250 fathoms the effect of the red and green rays was imperceptible even after a long exposure of plates especially prepared to register them. The ultra-violet and the blue rays are those which penetrate deepest. These records correspond closely with the observations of Hermann Foll in his diving expeditions in the Mediterranean. At a depth of 15 fathoms dark red animals looked to him quite black, whilst the green and blue-green algæ appeared lighter in colour. A coloured object of course looks black when untouched by rays of its own colour. In accord with this absence of red rays below 250 fathoms, we find a very large number of crustacea, some of them of considerable size, and all of a most brilliant red colour—scarlet as a boiled lobster—swimming about in the seas just below the lower limit of the penetration of the red rays. As a rule, however, in this region the fish are black in colour, though closely allied species of the same genus, variegated and light in hue, are swimming about in the upper waters.

Not only is there no light, but there is no sound at the bottom of the sea except for the rare explosion of a submarine volcano, and even when that occurs the noise must be somewhat muffled.

> "There is no sound, no echo of sound, in the deserts of the deep."

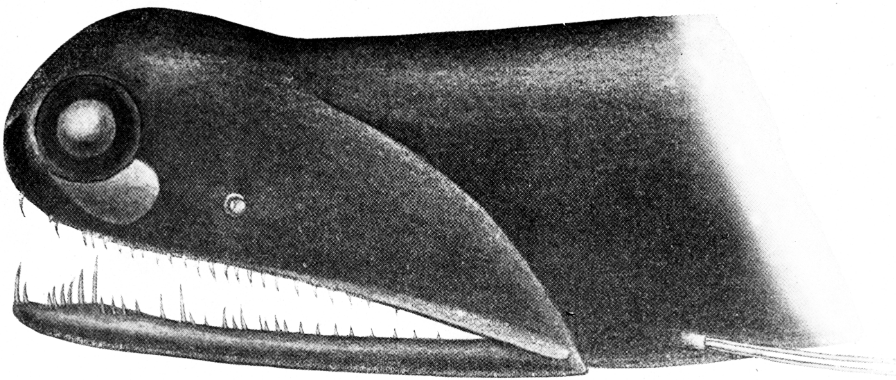
Down there all is dark, and all is silent. It is also confoundedly cold. The temperature of even the surface waters of the sea varies comparatively little compared with the fluctuations of heat and cold on land. On land temperatures as low as −90° C. and as high as 65° C. have been registered, showing a range of 155° C. At sea the range is only 33.8° C., lying between −2.8° C. and 31° C. As a rule, at the bottom of the deep sea there is a uniform low temperature. Whether in the tropics or in the polar regions, the bottom of the ocean registers a temperature of between 2° C. and zero,



Melanostomias melanops

1024 m. Indian Ocean near Sumatra. Natural size. Diagram showing arrangement of light-organs.

Light-organs are shown as follows: 1. A large half-moon-shaped movable organ behind the eye. 2. A smaller organ on the gill-cover. 3. A ventral row of 91. 4. A lateral row of 40. 5. Twelve between the gill-slits. All these organs are movable. In addition to these there are countless small light-organs scattered over the body in the arrangement indicated.



Malacosteus with Two Pairs of Light-organs

The light-organ located under the eye emits a ruby-red light during life; the hind one is shaped like an eye, lies in a pit, and emits a green light. ×4. South Atlantic Ocean. Within depth of 5000 m.

though in many places it falls below the freezing-point of fresh water.

These cold waters are, further, very still; at the bottom of the ocean there is a great calm. The waves that churn the surface overhead are unfelt at the depth of a few fathoms; even the great surface currents which stream along the upper waters of the ocean are hardly perceptible below some 200 fathoms. There are, of course—as the wear and tear of cables teach us—places where deep-sea currents are strong; but, on the whole, the abysses of the sea are cold, noiseless, and motionless. The monotony of the surroundings is increased by the fact that no diurnal or seasonal change reaches those great depths. Summer and winter, spring and autumn, are to them unknown; for them there is no such thing as night and day, seed-time or harvest. Probably the inhabitants of these abysses breed all the year round, as land forms do in the tropics. There we find insects and other animals showing no seasonal change of life, eggs, larvæ, chrysalises, imagoes all existing at one and the same time.

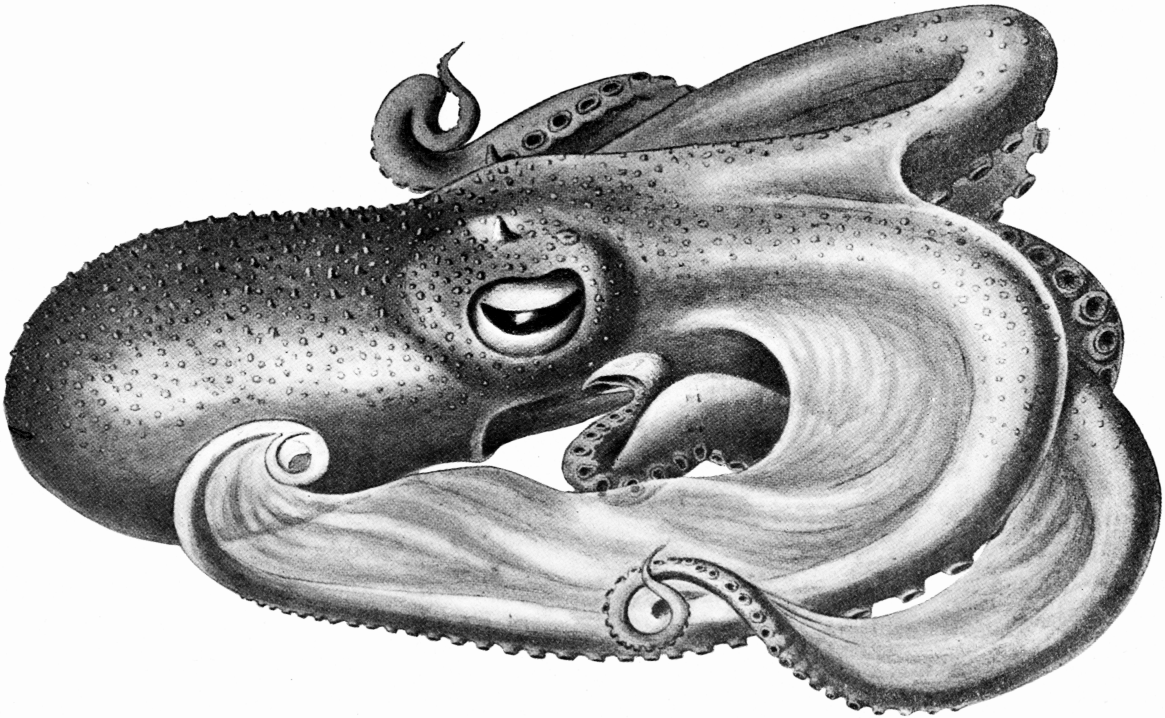
Deep-sea animals live at a tremendous pressure. Every five fathoms we descend in the sea the pressure increases by one atmosphere, and at a depth of 3000 fathoms the pressure on each square inch of the body of an animal amounts to three tons, whereas at the surface of the waters it is about fifteen pounds. So great is this pressure that unless special precautions are taken the glass of the thermometers which measure the bottom temperatures is crushed to powder.

It used to be thought that the depths of the sea were uninhabitable, and then again it was thought that could we explore them they would reveal animals known hitherto only as fossils, or perhaps indeed some strange creatures which would come into no class or subdivision of our modern zoölogical classifications. Neither of these conjectures has proved to be correct. The bottom of the sea is fairly well populated, and, with one or two not very striking exceptions, its exploration has revealed no persistent fossil types, and certainly no forms which do not readily fall into existing zoölogical systems. But the conditions which we have attempted to depict undoubtedly have had a great influence on the structure of the deep-sea animals. Many of them have retained and others have acquired a radial symmetry, and, planted as many of them are in the semi-fluid ooze exposed to a ceaseless shower of *Foraminifera,* they have acquired a certain "stalkiness." This "stalkiness" is shown by many of the cœlenterates and the sponges, by tunicates, and above all by the stalked sea-lilies. Animals with legs and tentacles have in the depths developed longer legs and longer tentacles. In fact, the tentacles are many times the length of the body, and stretch out through the water in all directions, acting in the place of eyes. In the fishes certain of the fin-rays are prolonged and, like the barbels and tentacles, act as sensitive outposts. Many deep-sea animals have become sightless; others, as they approach the bottom, develop larger and more efficient eyes, sometimes standing out from their heads like binoculars, or even borne on the ends of stalks, as is the case in some of the eight-armed cephalopods and in the larvæ of certain fishes.

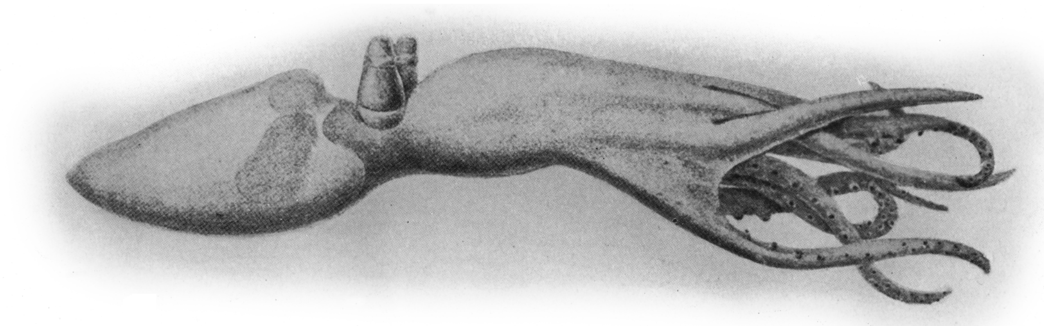
Many of the fish are black, and, what is more remarkable, they are dark inside as well as out. The cavity of the mouth and of the body are alike lined by tissues of the blackest hue. Others are almost transparent, and, indeed, one can easily read print through the body of a *Leptocephalus,* the larva of the common eel, which is so transparent that one would not be able to see it in a dish but for the presence of pigment in its eyes. But these larvæ pass up to the surface at a very early stage, and their transparency may be due to the fact that they are destined to a surface life. Many other forms are, however, very gorgeously coloured, and yet, as far as we know, "their glory is concealed," for there is no light and often no eye to note the brilliant blues—the oranges, the greens and reds, the violets and purples—which deck their bodies. Perhaps it may be connected with the temperature at which they live that they show a marked inability to secrete calcareous skeletons: the bones of deep-sea fishes are curiously soft and their scales thin. Their bodies, or muscles, have lost the usual elasticity, and when one pinches a hake, as when one pinches a patient suffering from beri-beri, the mark of the finger and thumb persists. Even the deep-sea sea-urchins present but a soft skeleton, the carapace of the crustacea becomes chitinous, and the shells of the mollusca thin and translucent. Calcareous sponges have not been found in the depths. The exact reason for this deficiency in the power of depositing lime is obscure. It is certainly not due to a lack of material dissolved in the surrounding waters; but it is curious to remark that animals with a flinty skeleton seem to show an increased power of secreting silica in deep-sea waters. Another unexplained peculiarity of deep-sea animals is their tendency to reduce the size of their breathing apparatus. The gills are reduced in number and in size, and in some cases have almost disappeared. There is also a great tendency amongst deep-sea organisms to produce spines and processes—a fact which is recorded over and over again in the specific names which systematists have applied to deep-sea forms.

One of the most novel experiments carried on by the *Michael Sars* was measuring, at varying depths, the actual velocity and strength of the current which passes in and out of the Straits of Gibraltar. By the use of Ekman's current-meter, Dr. Helland-Hansen was enabled to add very largely to our knowledge of the rate at which the upper water sweeps eastwards from the Atlantic into the Mediterranean, and the deeper waters sweep west. Hourly variation was very marked, and at times even the upper current went westwards. These variations appear to coincide with certain tidal movements.

Another remarkable feature of the Atlantic cruise was the number of nets and trawls the *Michael Sars* was able to keep out at once. Sometimes as many as seven or eight or even ten were dragging through the water at different levels on the same line. In this way very large collections were made at certain determined horizons, and these are now being worked out and will be published in full under the auspices of the Bergen Museum. It is interesting to note that the *Michael Sars* in its numerous dredgings found that the contents of the nets were, on the whole, practically identical in character when the nets were set at constant depths. Down to 75 fathoms there were small colourless fish of many species, fish eggs of many sizes, and larval eels in several stages of growth. These were accompanied by a series of transparent invertebrates of the usual pelagic type. From 150 down to 250 fathoms, small silvery fish with telescopic eyes, beautiful to look at but feeble swimmers, drifting hither and thither in the waters, were taken. But perhaps the most numerous of all fishes was a grey *Cyclothone;* and here too were found a number of red crustacea. Between 500 fathoms and 1000 fathoms the grey *Cyclothone* was replaced by a completely black but closely allied species; red prawns were still in abundance, and, what is more remarkable, red chætognaths and red nemertines, and there were also numerous species of black fishes and many dark brown medusæ. In these deeper hauls many animals of great rarity were taken: for instance, the little-known



New Genus of Eight-armed Cuttlefish with Broad Tentacles
East African Coast. 748 m. Half natural size.



Eight-armed Cephalopod (*Amphitretus*) with Telescopic Eyes

Agulhas Current. Within depth of 1800 m. Slightly enlarged.

cephalopod *Spirula* and a species of *Melanocetus,* the type of which was discovered only recently in the Indian Ocean. Other fish were also taken which had hitherto been found only in the Indian or the Pacific Ocean.

One of the triumphs of this expedition was to extend still further the brilliant researches of the Dane Schmidt into the obscure life-history of the common eel, supported as they had been by certain finds of the Irish Fishery Board. The *Michael Sars* captured younger stages of the larva (*Leptocephalus*) than had hitherto been taken; in fact, specimens found south of the Azores, and Hjort says he presumes "that this peculiar distribution can only be explained by supposing that the eel spawns south of the Azores and that the eggs and larvæ pass through their early stages there, being later carried into the North Atlantic and towards the coast of northern Europe by the Gulf Stream."

Although as a general rule the deep-sea forms tend to run rather small, there are exceptions to this, especially in the polar regions. There we find certain isopod crustacea, represented on land by the wood-louse and on our shores by small forms barely an inch long, growing to the size of cray-fish or lobsters; while very large pteropods, a group of floating mollusca, which at the surface seldom surpass an inch or two in length, have at great depths been taken over two feet long. Again, a remarkable *Appendicularia,* usually quite tiny, attains at great depths five inches in length with a notochord as big as a lamprey's. Many of these larger forms are found in the polar areas, and not only within the Arctic and Antarctic circles do the deep-sea forms surpass their shallow-water relatives in size, but the bottom fauna in these areas is peculiarly rich both in the number of species and in the number of specimens.

Animals which live at the sea-bottom, or on the shore or at moderate depths on the continental shelf, so long as they are embedded in the ooze, or attached to stones or burrowing in the mud, or lying on the ground with feeble or no power of locomotion, are known to students of the sea as Benthos. Another category of animals, and a very important one, is the Plankton. The Plankton comprises all animals that *drift.* They may have organs of locomotion, but their powers of movement are entirely insignificant compared with the currents which sweep them along. Few of the smaller ones, swimming as hard as they can, progress more than a few inches a day, and yet, in comparison with their bulk, their locomotor organs are really moving them along as fast as the legs of a cantering pony. Planktonic animals are, however, readily moved by the waves, by the wind, by the tide, but they have little control over their translocation. Now a great deal of the Plankton is confined to the surface of the sea, and here, if we examine the fauna, we shall find innumerable animals of very various kinds. We have first of all a large part of the Plankton consisting of such organisms as *Sagitta,* many marine worms, tunicates, small crustacea such as copepods—some of them as brilliant in colouration and design as any firework—many jelly-fishes, certain molluscs, and a few fish. But most important of all the members of the permanent Plankton are the protozoa and the minute algæ which swarm on the surface of the sea.

These algæ are the source of all life in the sea. They alone are capable, in the sunlight, of building up organic compounds out of the inorganic matter around them, and on them the whole of the marine fauna, from whales to the microscopic, unicellular protozoa, from the surface forms to the abysmal forms, ultimately depend for their food supply.

Then we have a second group of surface Plankton which is composed of the larval stages of fishes, molluscs, starfishes, sea-urchins, crustacea, worms, and many other groups. No matter where these animals lay their eggs, their larvæ, as a rule, float to the surface of the water and there drift hither and thither in incredible numbers. When one recalls the fact that the right-whale (*Balæna*), often fifty feet long, and perhaps the largest agglomeration of flesh—or protoplasm—is nurtured on the drifting, floating organisms, one appreciates the fact that the Plankton forms indeed a very large feature in the life of the sea.

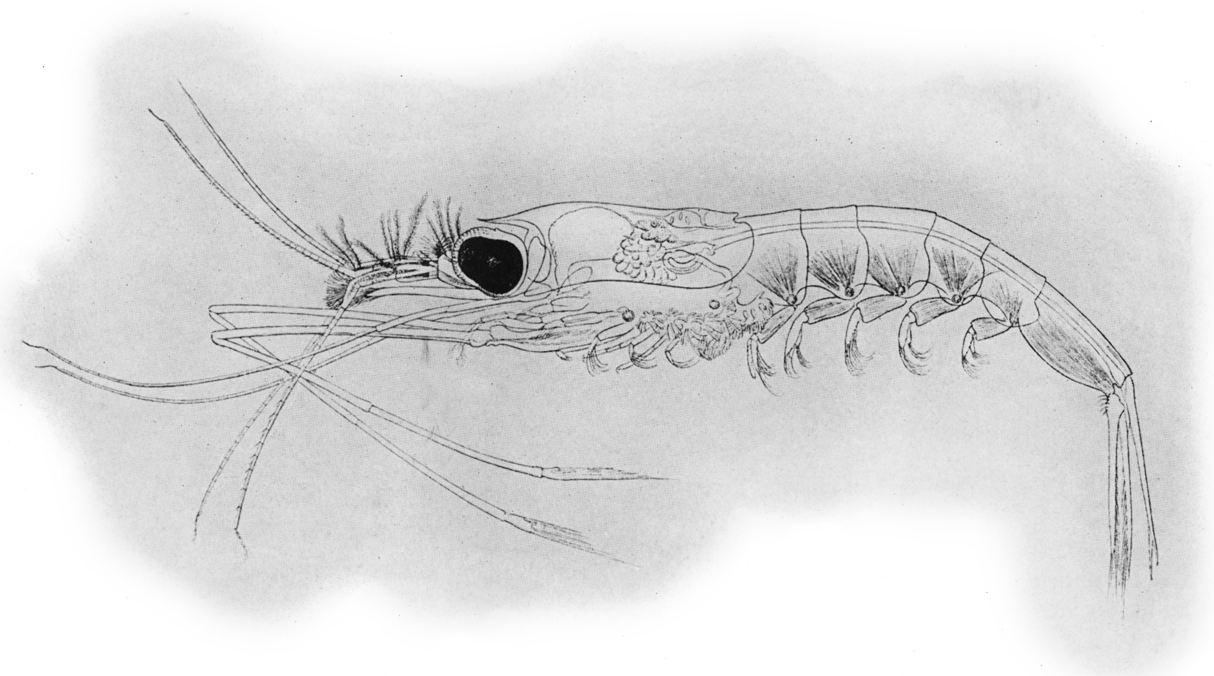
One of the most interesting contributions that the *Michael Sars* has made to our knowledge of this surface fauna is by Dr. Gran. He is responsible for a comprehensive chapter on the Phyto-plankton, or the drifting plant-life of the sea. Careful microscopic examination of the bottom of the sea revealed a long time ago certain calcareous rods and plates known as rhabdospheres and coccospheres, little calcareous bodies belonging to microscopic organisms. Systematically these skeletons belonged to organisms on the border-line between animals and plants, and these organisms are so minute that they are only occasionally caught by the finest-meshed nets that sweep the surface of the sea. So minute are they, that to separate them from the sea-water we have to use either an ultra-fine filter or an apparatus known as the centrifuge, which, whirling round at a great rate, is able to drive the solid matter suspended in the water to the furthest limits of the bottom of two rotating test-tubes. In the "Science of the Sea"[1] it is stated that "only the waters of the Mediterranean have been investigated for these forms by methods other than the ordinary tow-nets: it would be of

[1] "Science of the Sea," an elementary handbook of Practical Oceanography for travellers, sailors, and yachtsmen, prepared by The Challenger Society for the Promotion of the Study of Oceanography. Edited by G. Herbert Fowler, B.A., Ph.D., F.L.S., etc., sometime Assistant Professor of Zoölogy, University College, London. With illustrations and charts. Murray, 1912.

great interest to discover their distribution in oceanic waters generally." This Dr. Gran has done.

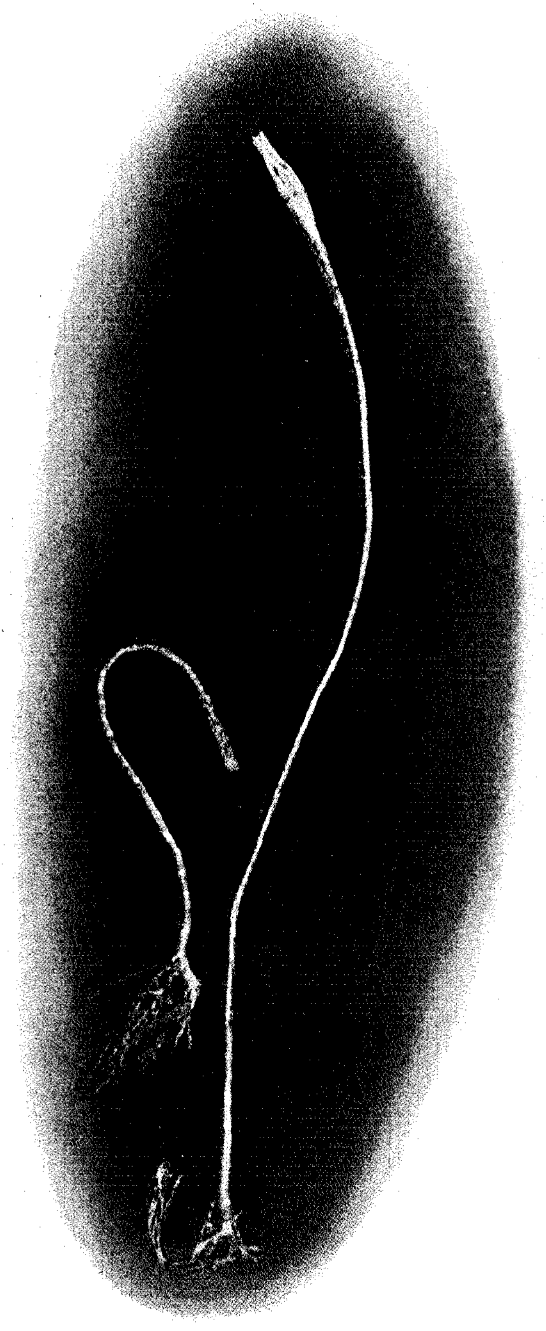
On the *Challenger* Sir John Murray used to obtain these microscopic creatures, now known as the *Coccolithophoridæ,* by allowing a glass of sea-water to stand for some hour's, when the organisms sank and attached themselves to fine threads placed at the bottom of the tumbler. As we have seen on more than one occasion, organisms of the minutest size have been also discovered by examining Nature's own filter, the pharynx or stomach of the salps which float about in the surface waters. The *Coccolithophoridæ* appear to be abundant in the open ocean of the tropical and sub-tropical waters, but they become rare at temperatures below 45° F. They exhibit a great variety of external forms. And, as Dr. Gran writes, notwithstanding their small dimensions these microscopic calcareous creatures occupy a very important place in the economy of the sea, and their shields of lime, which may be met with in geological deposits dating as far back as the Cambrian period, show that they have retained their shape practically unaltered through immeasurable ages.

They are almost entirely oceanic and mostly belong to the warmer seas. In coastal waters, where the salinity is lower, they are scarcer, but the commonest species, the little *Pontosphæra huxleyi,* has been found even in the Baltic, and there in such immense quantities (five to six million organisms per litre) that the calcareous cells with their strong refraction gave a milky appearance to the waters of the inner parts of the Christiania fiords during the hot summer of 1911. Dr. Gran carried on his investigations on these forms from the Canaries to Newfoundland, and thence across to the Irish coast, and as a result he came to the conclusion that these very minute organisms, which pass with ease through the meshes of the finest silk nets, are far more



Nematoscelis mantis Ch.

Depths of the Atlantic and Indian Oceans. ×6.



Rhizocrinus

East African Coast. 1668 m. ×1.5.

abundant than any others in the open sea, whilst the larger diatomes and the *Peridineæ* appear comparatively scanty in numbers although rich in species.

Dr. Gran made very careful investigations as to the depths to which the surface algæ sink,—the algæ which are the ultimate food supply for all the fauna of the sea. Samples were regularly taken from the surface and at depths of 10, 25, 37½, and 50 fathoms below the sea-level. At depths greater than 50 fathoms algal life was extremely scanty. The maximum algal life appears to lie somewhere about 25 fathoms, which corresponds with what Lohmann had found to be the case with the Mediterranean *Coccolithophoridæ.* This further corresponds with Schimper's observations made in the Antarctic during the *Valdivia* expedition. He found that the maximum of algal life lay between 20 and 30 fathoms, that it totally disappeared below 100 fathoms, and that the great bulk lay above the 50-fathom level.

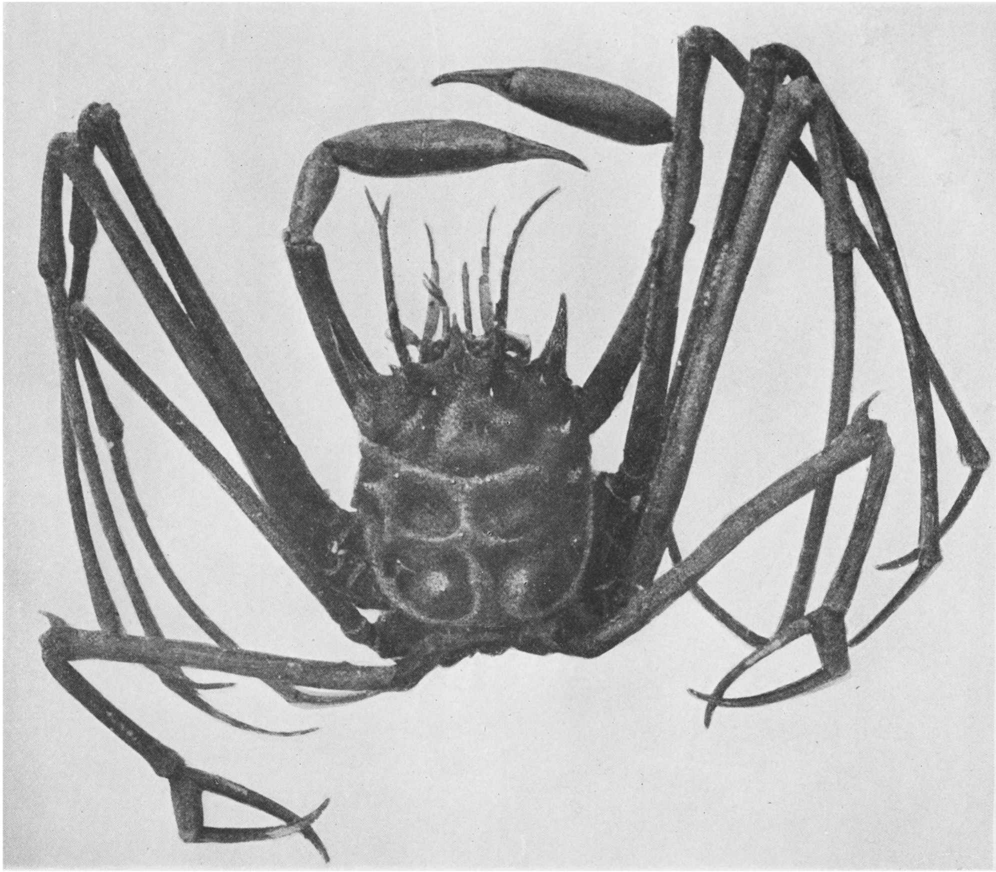
It has been observed by Hansen that plants in the sea are often so rare that it is difficult to understand how the animals can get enough nourishment, and yet the green and, as a rule, microscopic algæ have to produce enough food to support every single marine animal from the surface down to the deepest abyss. Hansen worked largely with vertical townets, through whose meshes these minute *Coccolithophoridæ* passed with ease. But taking everything into consideration, one would not feel very happy about one's food supply if one were a marine animal and thoroughly understood the economics of the ocean. The margin would strike one as very small.

Lohmann has studied, with the greatest minuteness and care, the quantities of all the Plankton organisms in Kiel Bay throughout a year, and he has calculated the volume of the various groups in the Plankton in the different water masses of this area at all seasons. In the winter months the algæ seem easily outnumbered by the animals, and from December to February they scarcely form a third of the total Plankton, the floating and drifting living organisms. In the summer months, however, they preponderate and make up sometimes as much as 75 per cent. of the total. He calculates that the plants *on an average* make up 56 per cent. and the animals 44 per cent. of the total drifting organisms in these regions—not a very large margin of safety for the animals.

It should perhaps be mentioned that much of this floating Plankton is, like the abysmal fauna, highly phosphorescent and is indeed the phosphorescence with which we are all familiar. It was surface phosphorescence that the ever-observant Pepys noticed when he described the "strange nature of the sea-water on a dark night, that it seemed like fire upon every stroke of the oar."

Between the floating Plankton on the surface and the inert Benthos at the base of the ocean, be it shallow or deep, are a number of actively swimming organisms—mostly fish, but also cuttlefish, whales, seals, dolphins and porpoises, crustacea, a few worms and medusæ, and a certain number of members of less well known groups. These forms are capable of swimming strongly and making headway against effective currents or tides and are collectively known as Nekton. They not only traverse wide stretches of water in the same horizon, but they are capable of descending and ascending vertically, and no doubt at times many of them form substantial additions to the larder of the animals living at the bottom.

During the last meeting of the British Association, which was held at Dundee, a discussion took place about life and the origin of life. Many learned professors expressed their



Homolochunia

Homolide with cephalic spines and claws on the fifth pair of legs.

—

East African Coast.

—

977 m.
Natural size.

opinions, but nobody seemed very successful in defining life. As far as one who was not there can form an opinion from the reports of the discussions, most of the authorities "came out by that same door wherein they went."

It is not easy to define life—in fact, it has not yet been done. We can only describe life by enumerating the attributes of living matter, and there is one attribute which is rather apt to be overlooked and may have been overlooked at Dundee. This is rhythm. Living matter is rhythmic. From the contractile vacuole of the amœba to the heart of man there is a definite repetition of action at more or less definite intervals, and there is, as Mr. Johnstone has so ably pointed out in his "Life of the Sea,"[1] a rhythm in the ocean.

There is a rhythm of the tide, a rhythm which corresponds with the rise and fall about twice every twenty-four hours, and that is involved in a still bigger fortnightly rhythm corresponding with the full and the new moon; for about halfway between these two phases the tide rises more slowly and to a lower height, and again, just as there is a half-daily and a half-monthly rhythm, so we have a half-yearly rhythm in the vernal and autumnal equinoxes. So regular are these rhythms that the tide is calculated years in advance, for all parts of the world, and navigators rely trustfully on these calculations, and the calculations are not found wanting.

This rhythmical change has impressed itself upon many marine organisms. As Mr. Johnstone reminds us, to keep cockles healthy in aquaria under artificial conditions one must run the water off the tank at least once a day so as to simulate a low tide. *Convoluta,* a small and lowly worm which lives on the sand and burrows beneath it when the tide is ebbing off the beach, kept in a laboratory in vessels of sea-water,

[1] "Life in the Sea," by James Johnstone, B.Sc. Fisheries Laboratory, University of Liverpool. Cambridge: University Press, 1911.

periodically burrows under the artificial sand at the bottom of the vessel when the real tide is normally going out. The phosphorescence of the surface organisms which we have noticed above only comes into play at best some time after sunset. If these surface organisms capable of producing phosphorescence be kept in an aquarium in a dark room, the same remains true. Although they are exposed to no secular change of light and darkness, they only show their lights at a time when the outside world is dark. The same is true, as Gamble and Keble have shown, with the chamæleon-shrimp, which in the sea shows a variety of protective colouring during the daytime, but at night becomes a transparent blue. Hence it is obvious that the tide has produced an effect which is lasting on certain organisms even when they have been removed from their natural surroundings and the tidal influence for considerable periods.

Then again we have a rhythmical change of temperature, which is fairly constant for given places in the sea. About February and March the sea is at its coldest, but it gradually warms up until in August it attains its highest normal temperature. Of course in all these rhythms there are many disturbing features, such as the weather. But these can fairly easily be discounted. Just as we have an annual rise and fall of temperature, so do we have a daily one, the temperature being at its lowest about sunrise, and gradually rising till about the middle of the afternoon. And again, there is a fortnightly rhythm, inasmuch as near the land the sea is warmer in the summer just after the time of new or full moon, and colder at the same periods during the winter.

Other rhythms might be pointed out, such as those dependent on the intensity of sunlight, and on the degree of salinity, which in turn depends to a very large extent on the water circulation of the sea. The pulsing up of the Gulf Stream is the direct result of this circulation, and affects not only the warmth but the salinity of the waters on our western shores. "The water is saltest when the drift is strongest, in the months of February to June, and is less salt when the drift is weakest, in the months of November to February." All these features have a profound influence on the life of the ocean, and a remote influence on land animals whose ancestry was marine.

A. E. SHIPLEY.